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Low-Temperature Ordering in $Pr_{1-x}Ca_xMnO_3$ Films

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Beamline: X22C

In the doping range of $0.3 \leq x \leq 0.7$, bulk $Pr_{1-x}Ca_xMnO_3$ exhibits a low-temperature, charge and orbitally ordered state, which can be destroyed via application of a magnetic field.[1] This melting of the charge and orbital order results in a dramatic drop in the resistivity (i.e., the so-called colossal magnetoresistance effect), and is of interest for possible use in devices. Since such devices would utilize the material in the form of a film, it is extremely important to characterize the low-temperature behavior of $Pr_{1-x}Ca_xMnO_3$ films. Working toward this goal, we have carried out x-ray scattering studies of $Pr_{1-x}Ca_xMnO_3$ films, with x = 0.3, 0.4, 0.5, for films grown on a variety of substrates.

All of the films were grown using the pulsed laser deposition technique. The films were cooled and the low-temperature ordering was investigated:

In $Pr_{0.7}Ca_{0.3}MnO_3$ films, 250-300 nm thick films grown on LAO and NGO substrates exhibit only short-range correlations with a maximum correlation length of ≤ 2 lattice constants. These correlations are observed to persist above the ordering temperature exhibited by bulk $Pr_{0.7}Ca_{0.3}MnO_3$.

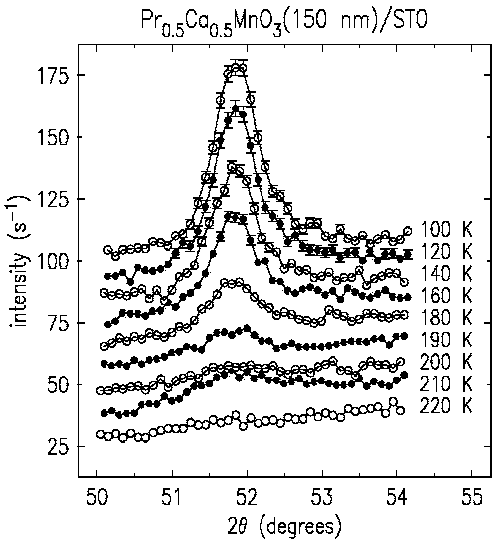
In $Pr_{0.6}Ca_{0.4}MnO_3$ films, 250-300 nm thick films grown on LAO and NGO substrates exhibited reduced ordering temperatures and shorter correlation lengths than in bulk, while a film of the same thickness grown on STO exhibited no low-temperature ordering. In all three films, room-temperature lattice constants were also measured, and the films were observed to exhibit a lower symmetry than in bulk (where it is orthorhombic).

In a 150 nm thick $Pr_{0.5}Ca_{0.5}MnO_3$ film grown on STO, low-temperature ordering was again observed with a reduced ordering temperature and a shorter correlation length. The former effect can be seen below—while the ordering in the film is observed to disappear below 220 K, the ordering temperature in bulk $Pr_{0.5}Ca_{0.5}MnO_3$ is ~245 K.[2] At this same doping and using the same substrate, a critical thickness for the ordering was also observed. That is, in a 120 nm thick film, no evidence of charge or orbital ordering was observed down to a temperature of 100 K.

The x-ray scattering studies of $Pr_{1-x}Ca_xMnO_3$ films have demonstrated that significant changes in behavior—compared to bulk—can occur, and that it is therefore important to study the low-temperature behavior of such films.

References

[1]Y. Tomioka, A. Asamitsu, H. Kuwahara, Y. Moritomo, and Y. Tokura, *Phys. Rev. B* **53**, R1689 (1996).
[2]M. v. Zimmermann, J.P. Hill, D. Gibbs, M. Blume, D. Casa, B. Keimer, Y. Murakami, Y. Tomioka, and Y. Tokura, *Phys. Rev. Lett*. **83**, 4872 (1999).



Θ-2Θ scans through the (2 1.5 0) orbital order peak. For clarity, each data set is shifted upward by 10 s^{-1} with respect to the next higher temperature data set.